ACOUSTIC CHARACTERISTIC OF PINEAPPLE LEAF FIBER

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SUPERVISOR'S DECLARATION

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the second examiner.

Signature : …………………………….

Name : …………………………….

Date : …………………………….

DEDICATION

To my beloved mother and late father

ABSTRACT

The current acoustic absorbers are made from synthetic materials is still applied comprehensively in building industry. These non-biodegradable materials are not only causing global warming and pollutions to the environment by increasing the CO^2 in the atmosphere during its production, but it also give negative effect to the human. Thus, researchers have their attention to find sustainable and eco-friendly materials which have the potential to replace the synthetic materials to be an alternative sound absorber. Pineapple leaf fiber is biodegradable material and it is available in plenty quantity as agricultural waste in Malaysia. In this study, the sound absorption of pineapple leaf fiber (PALF) is investigated to be a sustainable acoustic material. A samples sound absorber from pineapple leaf fiber is fabricated with different thickness, masses are tested using impedance tube according to ISO 10534-2 to measure the sound absorption coefficient. The effects of fiber density (mass), thickness, air gap and fabric on sound absorption performance are investigated. The performance of the sound absorption coefficient increase at the high frequency region due to the increment of the fiber density. The increment of thickness, application of air gap and added a layer of fabric at the samples increase the sound absorption coefficient especially at the lower frequency region. From the experimental result, samples at thickness 30 mm to 50 mm showed a good sound absorption performance where the average absorption coefficient is 0.98 in average frequency above 1000 Hz.

ABSTRAK

Penyerap akustik semasa diperbuat daripada bahan-bahan sintetik masih digunakan secara menyeluruh dalam industri pembinaan. Bahan-bahan ini tidak terbiodegradasi bukan sahaja menyebabkan pemanasan global dan pencemaran kepada alam sekitar dengan meningkatkan CO2 dalam atmosfera semasa pengeluaran, tetapi ia juga memberi kesan negatif kepada manusia. Oleh itu, penyelidik mempunyai perhatian mereka untuk mencari bahan mampan dan mesra alam yang mempunyai potensi untuk menggantikan bahan-bahan sintetik untuk menjadi penyerap bunyi alternatif. serat daun nanas adalah bahan mesra alam dan ia boleh didapati dalam kuantiti yang banyak sebagai sisa pertanian di Malaysia. Dalam kajian ini, penyerapan bunyi Pineapple Leaf Fiber (PALF) disiasat menjadi bahan akustik yang mampan. Sampel penyerap bunyi daripada gentian daun nanas adalah rekaan dengan ketebalan yang berbeza, berat diuji menggunakan tiub galangan mengikut ISO 10534-2 untuk mengukur pekali penyerapan bunyi. Kesan ketumpatan serat (jisim), ketebalan, ruang udara dan kain prestasi penyerapan bunyi disiasat. Prestasi peningkatan pekali penyerapan bunyi di rantau kekerapan yang tinggi disebabkan oleh kenaikan ketumpatan gentian. Peningkatan ketebalan, penggunaan ruang udara dan menambah lapisan kain pada sampel meningkatkan pekali penyerapan bunyi terutama di rantau frekuensi yang lebih rendah. Dari hasil eksperimen, sampel pada ketebalan 30 mm hingga 50 mm menunjukkan prestasi penyerapan bunyi yang baik di mana pekali penyerapan purata 0.98 dalam kekerapan atas rata-rata 1000 Hz.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Effective sound control can be attained with a complete understanding of sound phenomenon (Zhu et al., 2014). The sound energy that flow to the wall it can be either reflected back or absorb inside the wall. In order to reduce the sound energy, it must be absorb the sound energy. The sound energy will circulate throughout the building or any transmission path because the sound energy does not remain in the room. Reverberation time must be considered in room or in parts of the building where noise has to be reduced to reduce the echo. The wall of the building or room and around the structure must be containing the material that can absorb the sound energy in order to reduce noise in the building. Besides, there are need to find and choose properly material that capable to reduce or absorb the noise energy. Sound absorbing material will minimize reflection of the sound energy by converting it to heat through some frictional process in the absorber. Commonly, the sound absorbing material applied to walls and ceilings to reduce the noise and thus minimize sound reflection at the walls and it will reduce the sound level. Brickwork, concrete and sheet metal are good sound insulation because of the high mass per unit area but it have hard sound reflecting surfaces so it is still poor absorbers of sound. Based on Figure 1.1, it uses the glass wool at the wall to absorb the sound energy and Figure 1.2 shows the foam glass use at floor. Synthetic materials such as glass wool and foam glass are commonly used as sound absorber and these materials are found to be harmful to human health (Asdrubali, 2006).

Figure 1.1: Glass wool use at wall

Figure 1.2: Foam Glass use at floor

This synthetic material is not only harmful to human health but also cause pollution and global warming. Synthetic material also is more expensive material to use for sound absorption. Thus, researcher need to change the material used for sound absorption to the natural material which is it is more safe to use, easy to conduct and easy to get.

1.2 PROBLEM STATEMENT

Fiber synthetics as sound absorbing materials are commonly used because of their good performance and low cost and always used for thermal and sound insulation (Asdrubali, 2006). Even though the synthetic material is good for sound absorption and low cost but it also have negative side which is it can be harmful for human health for example lung alveoli, and cause the skin irritation. It also contributes to the discharge of carbon dioxide, methane and nitrous oxide (Arenas et al., 2010). Compared to the natural material which is have very low toxicity and the production does not effect to the environment. Due to the negative impact of using a synthetic material, the natural material has been widely used to produce sound absorption. There are many natural fiber ended up as wastes. One of the examples is pineapple leaf as shown in Figure 1.3. There has been a lack discussion on this natural fiber, particularly on its potential utilization as sound absorber. For this research, pineapple leaf fiber (PALF) is studied as alternative natural sound absorber.

Figure 1.3: Pineapple Leaf

1.3 OBJECTIVE

The main objectives of this project:

1) To extract fibers from the raw pineapple leaf.
2) To construct a different thickness and density (mass) samples of sound absorber panel from pineapple leaf fibers.
3) To measure the absorption coefficient of the fibers.

1.4 SCOPE

The focus of this study is to determine the acoustic performance of the pineapple leaf fiber only. In real life the sound energy come from any angle and any side, but in this study focuses on sound energy normal to the panel. The other properties of the pineapple leaf fiber for example structural strength, thermal conductivity and fire retardant are excluded during evaluating sound absorption coefficient.

CHAPTER 2

LITERATURE REVIEW

2.1 Porous Material

One of the methods to reduce the sound energy uses a sound-absorbing material. Sound absorbing material can absorb the sound energy which is sound energy less reflect through wall. Sound absorption material is classified three types which are porous, resonator and panel. This three type based on theory is transforming from sound energy to thermal energy (Lee. et al., 2003). A porous material is the material that can absorb the sound energy which is have high sound absorption coefficient. Porous absorber has a high absorption coefficient compare to Helmholtz resonator and panel resonator. Figure 2.1 shows the comparison sound absorber between porous, panel and cavity Helmholtz.

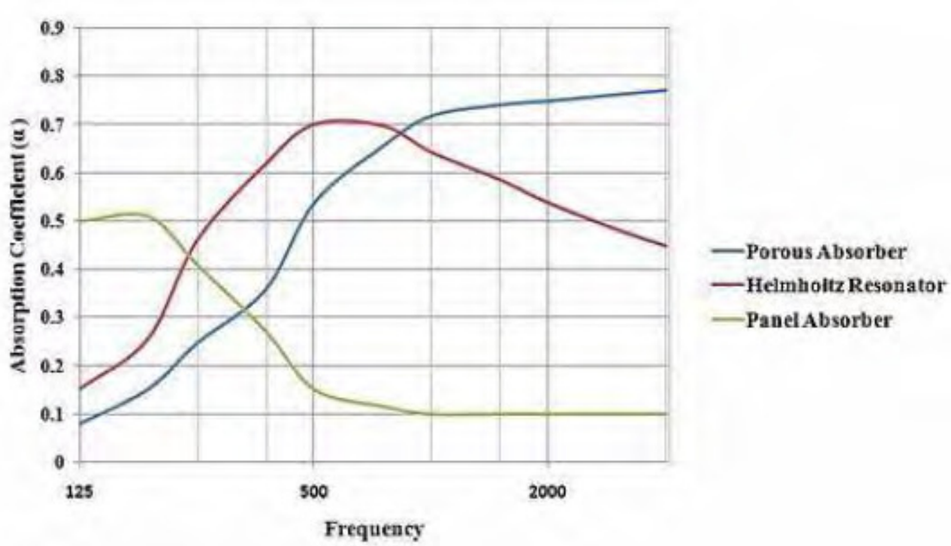

Figure 2.1: Variation of absorption with frequency for porous, panel and cavity Helmholtz

Porosity is known as ratio of the volume of void to the total volume of samples. There are three methods to determine the porous material which is dynamic, static method or simple calculation based on the density of the material (Wassilieff, 1996). A porous material is a solid that contain cavities, so the sound energy can flow through them. Porous material has a pore or closed pores but the open pores are more efficient compare to closed pore because the sound energy can flow through them but for the close pore the sound wave cannot flow. The open pore can influence the efficiency of the absorption of sound. The frictional force and the viscous will losses between the air in the pores (Kuczmarski. et al., 2011). According to Soto et al., (1993) using porous material in automotive industry for sound absorption result shows that the material that biggest pore size which is 1.1 mm with the thickness 5 mm is the most effective for sound absorption compare to the small pore size. Besides, the material that with same thickness but small pores size with a lot of interconnected cells is also good sound absorption at low frequency. Figure 2.2 show that the structure of the interconnected cell.

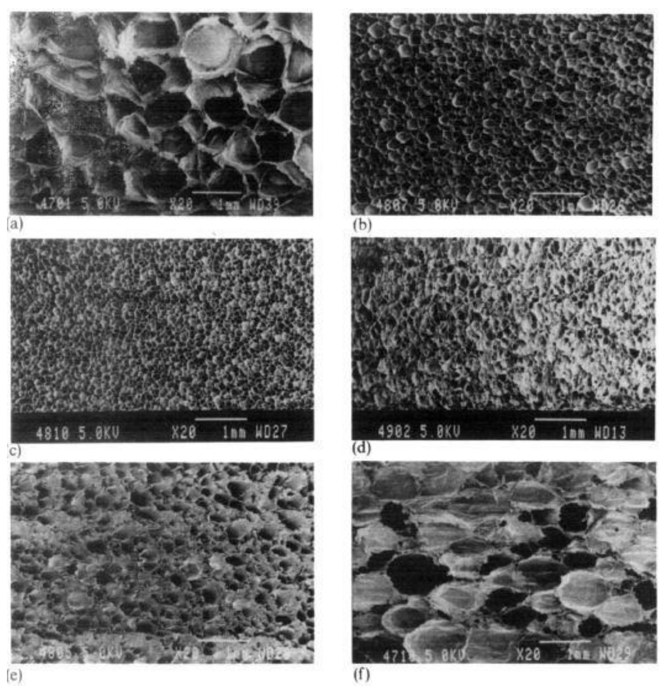

Figure 2.2: SEM micrographs of polyolefin closed cell foams (x20).

Same goes to porous ceramic material, according to Cuiyun et al., (2012) higher porosity could increase the highest sound absorption coefficient and increase the thickness of material improves the sound absorption at the low frequency. The comparison between porous zeolite and glass wool with different thickness 15 mm and 25 mm show that increases of the thickness of the sample could increase the sound absorption at the low frequency. The porosity of the porous zeolite is increase from 68.59% to 70.69% show that increase the sound absorption coefficient from 0.96 – 1.0. Figure 2.3 shows sample of the porous zeolite.

Figure 2.3: Sample of porous zeolite (Cuiyun et al., 2012)

Another porous material that has been done is comparison with glass wool and foam (Ovidiu et al, 2014). In this study, it shows that the number, size and pore type is the important factors need to be considered on the sound absorption in porous material. The surface of the porous material must have enough open pores in order the sound energy move through it. Flexible Polyurethane Foam (FPF) open pores with thickness 30 mm and Rigid Polyurethane Foam (RPF) closed pore with rate >90% with same thickness were analyzed. Figure 2.4 show the structure of the surface of the FPF and RPF. The frequency range 1250 Hz to 1600 Hz of the two material have a same value of sound absorption coefficient. Generally, it can observe that the material that opens pores has good sound absorption compare to closed pores material.

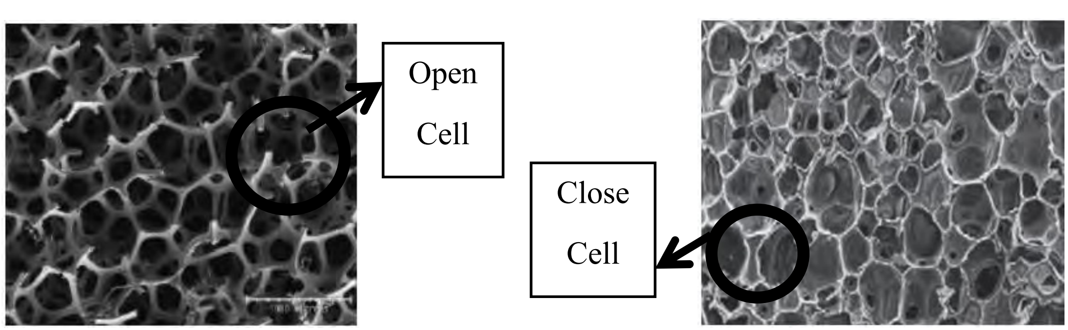

Figure 2.4: The cell structure of the RPF (left) and FPF (right) (Ovidiu et al, 2014)

2.2 Mechanism of Sound Absorption in Fibrous Materials

The sound energy that absorb by absorptive material is convert to heat. There are many authors and research has been done explained about the mechanism of the sound absorption (Delany et al., 1970; Bies et al., 2003; Wang et al., 2001; Barron 2003). According to Beranek, (1992) there are three mechanism of sound absorption, first is friction loss. Friction loss occur when the sound energy enter the porous material, the air molecule oscillate in between the porous material with the frequency of the sound energy. Next is momentum loss, change flow direction of sound energy due to fiber or irregular pores, this resulting momentum loss of sound wave. Lastly is change of temperature. Due to sound energy, the air molecules in the pores go through compression and relaxation. At low frequencies region, because of long travel, large surface to volume ratios and high heat conductivity of fibers, heat exchange occurs isothermally because of contacting between fiber and wave propagation. For high frequency region, compression takes place adiabatically which is there is no heat exchange occur during the travel. This is resulting to loss of sound and if the sound energy propagates parallel to the fibers, the sound energy losses up to 40% (Beranek, 1992).

2.3 Factors Influence Sound Absorption

2.3.1 Thickness

The thickness of the absorbent porous material has a relationship with the sound absorption at the low frequency. The thicker material the higher value of sound absorption coefficient and the thicker material are good absorption at low frequency compare to higher frequency range (Samsudin et al., 2016).

ALRahman et al., (2014), in this study comparison material between date palm fiber (DPF) and oil palm fiber (OPF) to compared sound absorption performance with different thickness which is 30 mm and 50 mm. Figure 2.5 shows the sample of fiber. Increase the thickness of the fiber, it increases the performance of the sound absorption but the peak frequency for both fiber shifted to low frequency region. Date palm fiber shows high sound absorption coefficient compare to oil palm fiber. For DPF with thickness 30 mm and 50 mm show 0.83 and 0.93 for maximum absorption at 2500 Hz and 1300 Hz, for OPF the highest absorption 0.60 and 0.75 at frequency 3500 Hz and 2000 Hz for thickness 30 mm and 50 mm.

Figure 2.5: Test samples of date palm fiber (left) and oil palm fiber (right) (ALRahman et al., 2014)

Masrol al., (2013), in this research investigate about the sound absorption of palm oil male flower spikes (POMFS) strengthened with polyutherene composite with different of thickness 8 mm, 25 mm, 35 mm. There are 5 different of POMFS, polyutherene with the ratio 5:95, 10:90, 15:85, 20:18 and 25:75. 5 % of POMFS shows that highest of the sound absorption coefficient by thickness 25 mm panel with 0.36 at 5800 Hz. The highest sound absorption coefficient for 10% POMFS is 0.37 at 6000 Hz for 8 mm thickness panel and for 25 mm thickness 15% POMFS shows highest absorption is 0.86. At the frequency 4100 Hz shows 20% POMFS is maximum absorption value is 0.78. Lastly, 25% of POMFS at the frequency 4100 Hz shows the sound absorption coefficient is 0.8.

Another study of factor influence sound absorption, Fouladi et al., (2013) by using coconut coir, corn, grass and sugar cane fibers with different thickness has been investigate in this research. Figure 2.6 and 2.7 show the coir fiber and corn fiber. The results show that the sound absorption coefficient (SAC) for corn fiber, highest absorption for corn fiber is 0.7 at 3000 Hz for 1 cm thick and with the increases of the thickness from 1 cm to 2 cm show that the peak frequency shifted from lower range to higher frequency range with the SAC 0.9 at 4000 Hz. For grass fiber, increases the thickness show improvement of SAC from 0.46 for 1 cm to 0.98 for 2 cm thick and peak frequency has been shifted from higher frequency range to lower frequency range. For sugar cane fiber, peak absorption remains constant after increase the thickness which is 0.88. The peak frequency shifted to lower frequency range when the thickness increases. Lastly, SAC of coir fiber increase from 0.46 at 4000 Hz to 0.97 at 2000 Hz from 1 cm thick to 2 cm thick of coir fiber.

Figure 2.6: Coir fiber in disk form Fouladi et al., (2013)

Figure 2.7: Corn fiber in disk form Fouladi et al., (2013)

Next, the study by Al-Rahman et al., (2012) investigates effect of thickness and compression of innovative material from date palm fiber (DPF) on sound absorption. 20 mm, 30 mm, 40 mm, and 50 mm thick tested by low and high frequency. Result show that increases the thickness of sample increase the absorption for lower range frequency. For 20 mm thick, maximum absorption is 0.64 at 3884 Hz, for 30 mm thick peak frequency is 0.83 from 4978 Hz to 5000 Hz. For 40 mm and 50 mm, the highest absorption at frequency 4950 Hz to 5000 Hz is 0.83 and 0.86 respectively.

Zulkifli et al., (2010) in research about the effect of porous layer backing (PLB) and perforated panel (PP) with different thickness of coconut coir fiber (CCF) 10 mm and 20 mm. Figure 2.8 show the sample, fiber and perforated panel. The highest absorption for 20 mm CCF without PLB and PP attained 0.83 at 3784 Hz and for 10 mm samples shows highest absorption of 0.39 at 5000 Hz. For the samples backed with layer of Woven Cotton Cloth (WCC), it shows the increases of peak absorption. For 10 mm CCF with WCC layer backing attained highest absorption of 0.96 at 3800 Hz and for 20 mm CCF with WCC achieved 0.97 at frequency range 2750 Hz-2825 Hz. The peak absorption was shifted to lower frequency range and remains constant when the sample attached with perforated panel (PP).

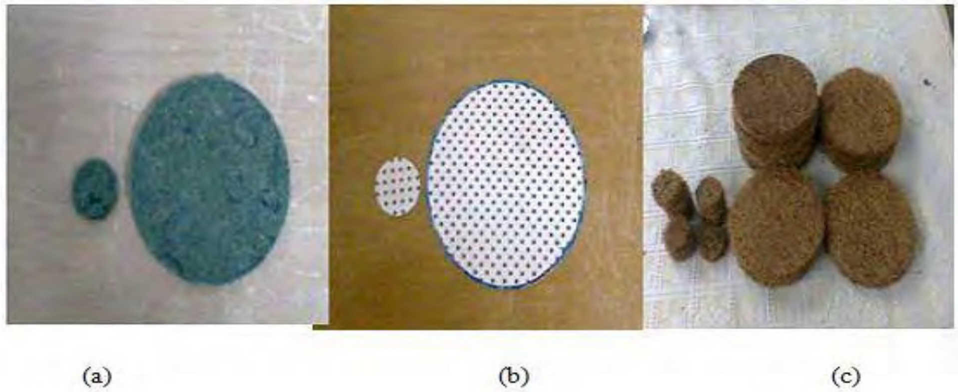

Figure 2.8: Test samples (a) porous layer (b) perforated panel (c) coconut coir fiber (Zulkifli et al., 2010)

Ersoy and Kucuk, (2009), research about tea leaf fiber (TLF) with different thickness 10 mm, 20mm and 30 mm. 10 mm thick TLF attained highest SAC of 0.26 in the frequency range 4000 Hz-6300 Hz. For 20 mm thick TLF show it peak absorption of 0.60 at 6300 Hz and for 30 mm thick TLF sample achieve 0.7 at 5600 Hz. For the sample backed with woven cotton cloth (WCC), 10 mm TLF sample shows that peak absorption is 0.8 at frequency range 5500 Hz-6300 Hz. For 20 mm and 30 mm thick, sound absorption coefficient value gradual increase at lower frequency region.

Another research about the sound absorption influence by the thickness of the material is research by Putra et al., (2013) using paddy fibers (PF) as sustainable acoustic material. Figure 2.9 show the sample of paddy fiber. PF samples were prepared with different thickness and different weight which is 10 mm and 20 mm and weight with 2 g and 4 g. For the samples PF with thickness 10 mm shows good performance with sound absorption coefficient (SAC) more than 0.5 above 3000 Hz and for the sample with 20 mm thickness it show that the absorption coefficient increase below 3500 Hz. Increasing the thickness of the samples, the sample may have more open pores which is the sound energy with high frequency can propagate easily (Putra et al., 2013).